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ABSTRACT

This study investigates the relationship of selected measures of proprioception to measures of physical growth, motor performance, and academic achievement in young children. Measures were obtained from 321 boys and girls attending kindergarten and first and second grade. Sample correlation matrices were computed on all variables at each grade level. Multivariate analysis of variance procedures were employed to determine grade and sex differences in performance on the proprioception tests. Multivariate multiple regression analysis was used to estimate the relationships between each of the dependent variables and the set of proprioception tests. Regression equations were established for the criterion dependent variables. Significant intergrade differences were found for performance on three of the proprioception tests. No significant performance differences due to sex were found for any of the proprioception tests at any grade level. Intercorrelations between proprioception scores and the measures of physical growth, motor performance, and academic achievement reached significance most frequently with the thickness discrimination and static balance tests. Significant intercorrelations between proprioception and academic achievement measures were most frequent at the kindergarten level and decreased with each succeeding grade. The predictive ability of the proprioception measures was greatest at the first-grade level. (Author)

THE RELATIONSHIP OF SELECTED MEASURES OF PROPRIOCEPTION TO PHYSICAL GROWTH, MOTOR PERFORMANCE, AND ACADEMIC ACHIEVEMENT IN YOUNG CHILDREN

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The subject of proprioception has received considerable attention in the research literature. However, those studies concerned with proprioceptive sensitivity have been limited, for the most part, to adult subjects. As a result, little is known concerning the developmental aspects of proprioception or of its relationship to the physical maturation, mental ability, academic achievement and gross motor performance in young children. It was the purpose of this investigation to seek answers to the following questions:

1. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?
2. Are measures of proprioceptive sensitivity related to measures of physical maturation, motor performance, mental ability and academic achievement?
3. To what extent can selected measures of physical maturation, motor performance, mental ability and academic achievement be predicted by performance on tests of proprioception?

Methods and Procedures

The sample of 321 boys and girls attended the kindergarten, first and second grades at two elementary schools in the Waverly Public School District near Lansing, Michigan. A total of 111 children (52 boys and 59 girls) were enrolled in the kindergarten classes, 119 (64 boys and 55 girls) in the first grade, and 91 (41 boys and 50 girls) in the second grade.

Data were collected from the subjects during the fall of 1969. The variables included in the study are presented in Table I. The physical growth, motor performance and proprioception tests were administered using standardized procedures during the last two weeks of September. The academic achievement and mental ability tests were given during the early part of October, to approximate the standard time for fall achievement testing in the Waverly School System. The tests were administered according to the directions in the test manual by trained personnel.

A battery of four proprioception tests developed by Robinson (1968) was administered to the subjects. The tests were administered individually with the subjects blindfolded. They included:

A. A measure of static balance without the use of visual cues (One Foot Balance)
B. A measure of bilateral integration of joint angle perception and limb positioning (Parallel Blocks)

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TABLE I

MEASURES INCLUDED IN STUDY

PHYSICAL GROWTH

- Standing Height
- Weight
- Ponderal Index

MOTOR PERFORMANCE

- Ball Bounce and Catch
- Body Part Identification
- Directionality
- Dynamic Balance
- Static Balance: 1 1/2" Rail
- Static Balance: 1" Rail
- Reaction Time: Auditory
- Reaction Time: Visual
- Standing Long Jump
- Stationary Ball Dribble

MENTAL ABILITY

- Kindergarten: None
- First Grade: Otis-Lennon; Primary II
- Second Grade: Otis-Lennon; Elementary I

ACADEMIC ACHIEVEMENT

- Kindergarten: Stanford Early School Achievement Test - Level I
- First Grade: Stanford Early School Achievement Test - Level II
- Second Grade: Stanford Achievement Test - Primary I

PROPRIOCEPTION

- Bilateral Integration: Parallel Blocks
- Static Balance: One Foot Balance
- Thickness Discrimination: Contrast Blocks
- Weight Discrimination: Contrast Blocks

C. A measure of fine joint angle perception and judgment of "length" (Thickness Discrimination)

D. A measure of sensitivity to fine muscle tension (Weight Discrimination)

Descriptive statistics including means and standard deviations were computed for each of the four proprioceptive tests by grade level. Multivariate analysis of variance procedures (Finn, 1967) were employed to determine grade and sex differences in performance on the proprioception tests. Sample correlation matrices (Finn, 1967) were computed on all variables at each grade level. Multivariate multiple regression analysis (Finn, 1967) was used to estimate the relationship between each of the dependent variables and the set of proprioception tests.

Results

1. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?

The mean and standard deviation scores for each of the proprioception tests at each grade level are presented in Table II. Performance in static balance improved from grade to grade for both boys and girls, however, there was large interindividual variability in performance as denoted by the standard deviation values. Performance on the test for bilateral integration of joint angle perception and limb positioning was assessed by using a mean error score, therefore, superior performance is indicated by a low score. There is little difference in the magnitude of the means for this test when comparisons are made between grades. Performance on the Thickness Discrimination and Weight Discrimination tests was scored by summing weighted error scores involving judgments on paired comparisons of thicknesses or weights. Intergrade mean differences followed a sequential pattern from the kindergarten to the second grade for both measures, with the second grade children being the most proficient in thickness and weight discrimination. Again, interindividual performance variability was large for both measures.

When a MANOVA procedure (Finn, 1967) was used, a significant generalized multivariate F ratio for the main effect of grade level was obtained. (See Table III). The F ratio of 10.62 with 8 and 612 degrees of freedom is significant at the .0001 level. Examination of the four univariate F statistics for significance reveals that three of the tests are essentially responsible for the multivariate effect - the One Foot Balance, Thickness Discrimination, and Weight Discrimination tests. The test of bilateral integration does not appear to be affected by grade level. Since the design was non-orthogonal, separate analyses for sex differences at each grade level were made. (See Table IV). No significant differences were noted at any grade level.

2. Are measures of proprioceptive sensitivity related to measures of physical growth, motor performance, mental ability and academic achievement?

Sample correlation matrices were computed for performance on all the variables for each of the grade levels. Intercorrelations between performance on the proprioception tests and the physical growth and motor performance measures are presented in Table V. Twenty-eight or approximately 18 percent of the 156 intercorrelations coefficients obtained were significant at the .05 level. All but three of these involved either the One Foot Balance or Thickness Discrimination tests. As might be expected, performance on the One Foot Balance Test and the Rail Balance items were significantly related to each other at all three grade levels. In addition, the coefficients for dynamic balance were also significant for kindergarten and

TABLE II

MEANS AND STANDARD DEVIATIONS FOR THE PERFORMANCE OF CHILDREN ON FOUR TESTS OF PROPRIOCEPTION

Grade	One Foot Balance		Parallel Blocks		Thickness Discrimination		Weight Discrimination	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kindergarten	3.18	2.32	34.47	16.84	6.22[a]	4.25	10.55	6.17
First	4.75	5.56	33.48	14.71	5.62	4.12	6.52	4.02
Second	6.00	4.30	34.39	13.75	4.59	3.79	5.36	4.04

[a]Scores for kindergarten groups represent errors for two series of judgments rather than three series.

TABLE III

MULTIVARIATE ANALYSIS OF VARIANCE FOR PERFORMANCE ON TESTS OF PROPRIOCEPTION; ILLUSTRATING THE EFFECT OF SCHOOL, SEX, AND GRADE

Source of Dispersion	df	Variable	Univariate F	Univariate P	Multivariate F	Multivariate P
School	1	OFB[a]	0.78	.377		
		PB	0.38	.537		
		TD	4.51	.035		
		WD	0.12	.729	1.45	.217
Sex	1	OFB	3.03	.083		
		PB	2.92	.088		
		TD	2.19	.140		
		WD	0.99	.320	2.27	.062
Grade	2	OFB	11.76	.0001[b]		
		PB	0.09	.909		
		TD	4.93	.008		
		WD	32.84	.0001	10.62	.0001
School by sex	1	OFB	2.05	.153		
		PB	0.75	.386		
		TD	2.69	.102		
		WD	2.14	.145	1.67	.158
School by grade	2	OFB	0.32	.723		
		PB	0.06	.946		
		TD	0.78	.459		
		WD	0.16	.854	0.35	.945
Sex by grade	2	OFB	0.30	.739		
		PB	1.59	.206		
		TD	0.31	.737		
		WD	1.49	.228	0.97	.455
Sex by grade by school	2	OFB	1.95	.144		
		PB	0.63	.533		
		TD	0.62	.537		
		WD	1.92	.148	1.34	.222

[a]OFB = One Foot Balance; PB = Parallel Blocks; TD = Thickness Discrimination; and WD = Weight Discrimination.

[b]Probability values were rounded off to the nearest .001 unless otherwise stated.

TABLE IV

MULTIVARIATE ANALYSIS OF VARIANCE FOR PERFORMANCE ON TESTS OF PROPRIOCEPTION; SHOWING THE EFFECT OF SCHOOL AND SEX

Source of Dispersion	df	Variable	Univariate F	Univariate P	Multivariate F	Multivariate P
		Kindergarten				
School	1	OFB[a]	0.18	.672		
		PB	0.01	.942		
		TD	5.82	.018		
		WD	0.13	.716	1.44	.227
Sex	1	OFB	1.47	.228		
		PB	0.06	.810		
		TD	0.72	.398		
		WD	1.43	.234	0.92	.457
School by sex	1	OFB	0.18	.668		
		PB	0.55	.459		
		TD	0.00	.945		
		WD	4.15	.044	1.25	.294
		First Grade				
School	1	OFB	0.96	.330		
		PB	0.21	.649		
		TD	0.70	.405		
		WD	0.03	.868	0.48	.753
Sex	1	OFB	1.69	.196		
		PB	1.75	.189		
		TD	2.19	.142		
		WD	0.40	.530	1.56	.139
School by sex	1	OFB	3.63	.059		
		PB	0.02	.886		
		TD	2.82	.096		
		WD	0.02	.885	1.53	.199
		Second Grade				
School	1	OFB	1.13	.289		
		PB	0.46	.501		
		TD	1.12	.292		
		WD	0.65	.422	0.78	.541
Sex	1	OFB	0.42	.519		
		PB	4.84	.030		
		TD	0.01	.908		
		WD	0.66	.420	1.60	.183
School by sex	1	OFB	0.08	.776		
		PB	2.29	.134		
		TD	0.78	.379		
		WD	0.03	.871	0.89	.472

[a]OFB = One Foot Balance; PB = Parallel Blocks; TD = Thickness Discrimination; and WD = Weight Discrimination.

TABLE V

INTERCORRELATIONS BETWEEN PERFORMANCE ON TESTS OF PROPRIOCEPTION AND ON SELECTED MEASURES OF PHYSICAL GROWTH AND MOTOR PERFORMANCE FOR KINDERGARTEN, FIRST AND SECOND GRADES

Variable	One Foot Balance			Parallel Blocks			Thickness Discrimination			Weight Discrimination		
	Kgn	G-1	G-2	Kgn	G-1	G-2	Kgn	G-1	G-2	Kgn	G-1	G-2
Physical Growth:												
Standing height	10[a]	-20*	11	03	-19	-05	-10	01	-08	-17	-13	11
Weight	08	-20*	06	02	-25*	-07	-03	-09	-05	-17	-08	09
Ponderal index	04	00	12	04	10	-00	-10	-14	-02	-02	-07	03
Motor Performance:												
Standing long jump	23*	14	16	04	-07	-24*	-23*	-2[illegible]*	-27*	-05	-06	-14
Rail blance: 1 1/2" rail	32*	46*	38*	-01	-14	-01	-12	-17	07	-10	-18	10
Rail balance: 1" rail	32*	31*	34*	-12	-14	-08	-23*	-16	-07	-01	-09	-08
Reaction time: auditory	-13	-04	-08	10	-05	14	06	21*	21*	11	04	-06
Reaction time: visual	-10	-11	-07	15	-02	13	11	31*	19	15	-00	-06
Body part identification	02	12	07	-16	08	19	-04	-17	-25*	02	-16	01
Directionality	03	01	07	-04	06	04	-10	-15	-00	-10	-16	-01
Dynamic balance	34*	14	29*	-10	-07	00	-20*	-14	-03	04	-07	09
Bouncing and catching a ball	19	15	26*	07	-22*	-11	-11	-36*	-26*	-01	-17	05
Stationary ball dribble	26*	13	16	09	-10	-09	-12	-32*	-15	-04	-15	15

[a]Decimal points have been omitted. Kgn (N=111), G-1 (N=119), G-2 (N=91)

*Significant at the .05 level.

second grade children. Significant intercorrelations were found at all grade levels for performance on the Thickness Discrimination test and the Standing Long Jump. The ability to judge thickness was also related to auditory reaction time and ball bouncing and catching ability in first and second grade children. No consistent patterns of relationships were noted for the tests of bilateral integration and weight discrimination. None of the individual coefficients were of great magnitude.

Intercorrelations for performance on the tests of proprioception and the measures of academic achievement and mental ability are presented in Table VI. Eight (50 percent) of the coefficients were significant at the kindergarten level. Only seven of 28 (25 percent) and two of 28 (seven percent) were significant at the first and second grade levels, respectively. This denotes a trend toward greater specificity with advancing grade levels for performance on the proprioception measures as related to performance on the academic achievement variables. Thickness Discrimination scores correlated most consistently with the academic achievement measures, particularly at the first grade level. All of the significant individual intercorrelation coefficients were of low magnitude and have little predictive value.

3. To what extent can selected measures of physical growth, motor performance, mental ability and academic achievement be predicted by performance on tests of proprioception?

Multivariate multiple regression analysis was employed to estimate the relationships between each dependent variable and the set of four independent proprioception tests at each grade level. Statistics for the regression analysis with the four tests of proprioception are presented in Tables VII, VIII and IX. At the kindergarten level (Table VII) six of the 17 dependent variables are significantly influenced by the addition of the test of proprioception to the regression equation. These include the standing long jump, the three balance items, the aural comprehensing subtest and the total score for the academic achievement test. However, the multiple R's generated are quite low. The greatest value of .437, for the aural comprehension test, indicates that only about .197 of the variability for performance on this test is accounted for by the regression equation.

Significant F ratios were obtained on 13 of the 20 dependent variables for first grade children (Table VIII). These included weight, height, standing long jump, static balance, visual reaction time, ball bounce and catch, ball dribble, mathematics, letters and sounds, word reading, and mental ability. The highest multiple R obtained was .517 for the 1 1/2" rail balance. Again, the magnitude of the multiple correlations generated was not sufficient to merit consideration for predictive purposes.

Only five F ratios for the 20 dependent variables were significant at the second grade level (Table IX). These were the standing long jump, the two static balance tests, body part identification, and the ball bounce and catch test. As can be noted, the multiple R's obtained were also the lowest for any of the three grades. The highest value was .407 for the 1 1/2" rail balance.

Discussion

The descriptive statistics and the MANOVA procedures applied to the data demonstrated grade level differences for three of the four tests of proprioception: the One Foot Balance, the Weight Discrimination Test; and the Thickness Discrimination measure. No intergrade differences were evident for performance on the test of bilateral integration of joint angle perception. No significant sex differences were found in performance on any of the four tests. These results suggest that some

TABLE VI

INTERCORRELATIONS BETWEEN PERFORMANCE ON TESTS OF PROPRIOCEPTION AND ON MEASURES OF INTELLECTUAL ACHIEVEMENT

Measure	One Foot Balance	Parallel Blocks	Thickness Discrimination	Weight Discrimination
Kindergarten				
Academic Achievement				
Mathematics	10[a]	-02	-16	-25*
Letters & Sounds	22*	05	-04	-07
Aural Comprehension	30*	01	-30*	-22*
A.A. - total	24*	-05	-20*	-30*
First Grade				
Academic Achievement				
Mathematics	-08	01	-26*	-16
Letters & Sounds	-03	03	-33*	-08
Aural Comprehension	02	17	-20*	-09
Reading Sentences	02	12	-22*	-11
Word Reading	08	09	-28*	-09
A.A. - total	00	15	-31*	-14
Mental Ability	01	12	-30*	-12
Second Grade				
Academic Achievement				
Word Reading	-10	-23*	-14	01
Paragraph Meaning	07	-16	-16	-02
Vocabulary	15	03	-17	-03
Word Study Skills	15	-23*	-18	-01
Mathematics	16	-09	-19	-05
A.A. - total	14	-17	-18	-02
Mental Ability	10	04	-13	05

[a]Decimal points have been omitted.

*Significant at the .05 level.

TABLE VII

STATISTICS FOR REGRESSION ANALYSIS WITH FOUR TESTS OF PROPRIOCEPTION: KINDERGARTEN

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth				
Standing height	.043	.207	1.19	.320
Weight	.038	.195	1.04	.389
Ponderal index	.012	.109	0.32	.864
Motor Performance				
Ball bounce and catch	.042	.206	1.18	.325
Body part identification	.031	.177	0.86	.489
Directionality	.020	.140	0.53	.715
Dynamic balance	.139	.373	4.29	.003
Rail balance: 1 1/2" rail	.121	.347	3.63	.008
Rail balance: 1" rail	.164	.405	5.21	.0008
Reaction time: auditory	.047	.217	1.32	.269
Reaction time: visual	.067	.259	1.91	.114
Standing long jump	.087	.295	2.53	.045
Stationary ball dribble	.077	.278	2.22	.072
Academic Achievement				
Mathematics	.083	.288	2.40	.054
Letters and sounds	.054	.233	1.52	.202
Aural comprehension	.191	.437	6.25	.0002
Academic achievement - total	.171	.413	5.45	.0005

[a]All probability values are rounded to the nearest .001 unless otherwise noted.

TABLE VIII

STATISTICS FOR REGRESSION ANALYSIS WITH FOUR TESTS OF PROPRIOCEPTION: FIRST GRADE

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth:				
Standing height	.103	.320	3.26	.014
Weight	.124	.352	4.02	.004
Ponderal index	.028	.168	0.83	.507
Motor Performance:				
Ball bounce and catch	.220	.469	8.02	.0001
Body part identification	.060	.246	1.84	.127
Directionality	.046	.214	1.36	.251
Dynamic balance	.043	.208	1.29	.277
Rail balance: 1 1/2" rail	.267	.517	10.39	.0001
Rail balance: 1" rail	.134	.366	4.41	.002
Reaction time: auditory	.044	.209	1.31	.271
Reaction time: visual	.106	.326	3.39	.012
Standing long jump	.081	.285	2.51	.045
Stationary ball dribble	.141	.376	4.68	.002
Academic Achievement and Mental Ability				
Mathematics	.097	.311	3.06	.019
Letters and sounds	.117	.342	3.78	.006
Aural comprehension	.065	.256	2.00	.100
Word reading	.088	.296	2.74	.032
Reading sentences	.062	.250	1.90	.116
Academic Achievement - total	.116	.341	3.75	.007
Mental ability	.105	.323	3.33	.013

[a]All probability values are rounded to the nearest .001 unless otherwise noted.

TABLE IX

STATISTICS FOR REGRESSION ANALYSIS WITH FOUR TESTS OF PROPRIOCEPTION: SECOND GRADE

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth:				
Standing height	.035	.188	0.79	.536
Weight	.022	.147	0.48	.753
Ponderal index	.016	.125	0.34	.849
Motor Performance:				
Ball bounce and catch	.135	.367	3.35	.013
Body part identification	.115	.339	2.80	.031
Directionality	.006	.080	0.14	.968
Dynamic balance	.092	.304	2.19	.077
Rail balance: 1 1/2" rail	.166	.407	4.28	.003
Rail balance: 1" rail	.124	.352	3.03	.022
Reaction time: auditory	.075	.274	1.75	.147
Reaction time: visual	.062	.248	1.41	.237
Standing long jump	.140	.374	3.50	.011
Stationary ball dribble	.082	.286	1.91	.116
Academic Achievement and Mental Ability:				
Word reading	.076	.276	1.78	.141
Paragraph meaning	.048	.220	1.09	.364
Vocabulary	.045	.211	1.01	.409
Word study skills	.093	.304	2.19	.076
Mathematics	.058	.242	1.34	.263
Academic Achievement - total	.070	.264	1.61	.179
Mental ability	.034	.184	0.75	.558

[a] All probability values were rounded to the nearest .001.

of the conponents of proprioceptivity are still undergoing developmental change during the age period studied. Whether this is the result of maturation and/or experience is not determinable from the results obtained.

The improvement of static balance with age has been reported previously (Miles, 1922; Espenschade, 1947; Fleishman, 1964). The results obtained in this study are in general agreement with the findings of these earlier studies, however, significant sex differences were reported by Miles (1922) and Fleishman (1964).

The ability to perceive fine joint angle variations follows a pattern similar to that of static balance. The significant relationship of the ability to judge thickness to several motor performance measures as well as to academic achievement at the kindergarten and first grade levels warrants that it receive attention in subsequent research involving small manipulative tasks.

Sensitivity to weight was also found to change with age. This is in agreement with the results obtained by Ormann (1923) when assessing this ability in young piano students. The absence of relationships between weight judgment scores and activities such as the ball bounce and catch, and the ball dribble tests is somewhat surprising. It would seem that sensitivity to force or resistence would be a crucial factor for successful performance on these tasks. Perhaps fine discriminations, such as those required for lifting weights, are not required for these activities.

Performance on the limb positioning task (Parallel Blocks) did not change from one grade level to the next, nor were sex differences apparent with this task. Witte (1962) also did not find sex differences on arm positioning measures administered to children ages seven to nine.

Results of the correlational analyses are in general agreement with those obtained in previous studies. The significant intercorrelations between measures of proprioception and those of physical growth, motor performance and academic achievement are generally of a low, positive nature. The specificity of these measures has been demonstrated previously with adults (Scott, 1955; Hempel and Fleishman, 1955; Fleishman, 1958). The results of this study suggest that this is also true for young children. On the other hand, the results also indicate that significant intercorrelations occur more frequently at the kindergarten level than at the other two grade levels, and particularly with the academic achievement measures. In addition, the only significant intercorrelations between the tests of proprioception were obtained from the kindergarten children. These results, plus the findings of other investigators (Abel, 1936; Thomas and Chissom, 1972) generate a growing suspicion that a trend toward greater specificity occurs in the behavioral responses of young children as they proceed from kindergarten through the early elementary grades.

Summary

Selected measures of physical growth, motor performance, academic achievement and proprioception were administered to 321 children in the Waverly Public School District near Lansing, Michigan. Analysis of the proprioception data by multivariate analysis of various procedures revealed no significant performance differences due to sex, but did not indicate significant intergrade differences on three of the four proprioception measures. These included the One Foot Balance, Weight Discrimination and Thickness Discrimination measures.

Intercorrelations between proprioception scores and the measures of physical growth, motor performance and academic achievement reached significance most frequently with the thickness discrimination and static balance tests; however, none of the coefficients exceeded .46. Significant intercorrelations between proprioception and academic achievement measures were most frequent at the kindergarten level and decreased with each succeeding grade. The predictive ability of the proprioception measures was greatest at the first grade level. The multiple R's obtained were generally of a low, positive nature with the highest coefficient have a magnitude of .52.

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